



(19) Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 499 641 A1

(12)

**EUROPEAN PATENT APPLICATION
published in accordance with Art.
158(3) EPC**

(21) Application number: 90916076.4

(51) Int. Cl. 5: G06F 3/03, G06K 11/16

(22) Date of filing: 31.10.90

(86) International application number:
PCT/JP90/01397

(87) International publication number:
WO 91/06907 (16.05.91 91/11)

(30) Priority: 01.11.89 JP 282852/89

(43) Date of publication of application:
26.08.92 Bulletin 92/35

(84) Designated Contracting States:
DE FR GB IT

(71) Applicant: WACOM CO., LTD.
23-4, Sakurada 5-chome Washinomiyacho
Kitakatsushika-gun Saitama-ken, 340-02(JP)

(72) Inventor: MURAKAMI, Azuma, c/o WACOM
CO., LTD.
23-4, Sakurada 5-chome, Washinomiyacho

Kitakatsushika-gun, Saitama 340-02(JP)
Inventor: YAMANAMI, Tsuguya, c/o WACOM
CO., LTD.

23-4, Sakurada 5-chome, Washinomiyacho
Kitakatsushika-gun, Saitama 340-02(JP)
Inventor: FUNAHASHI, Takahiko, c/o WACOM
CO., LTD.

23-4, Sakurada 5-chome, Washinomiyacho
Kitakatsushika-gun, Saitama 340-02(JP)

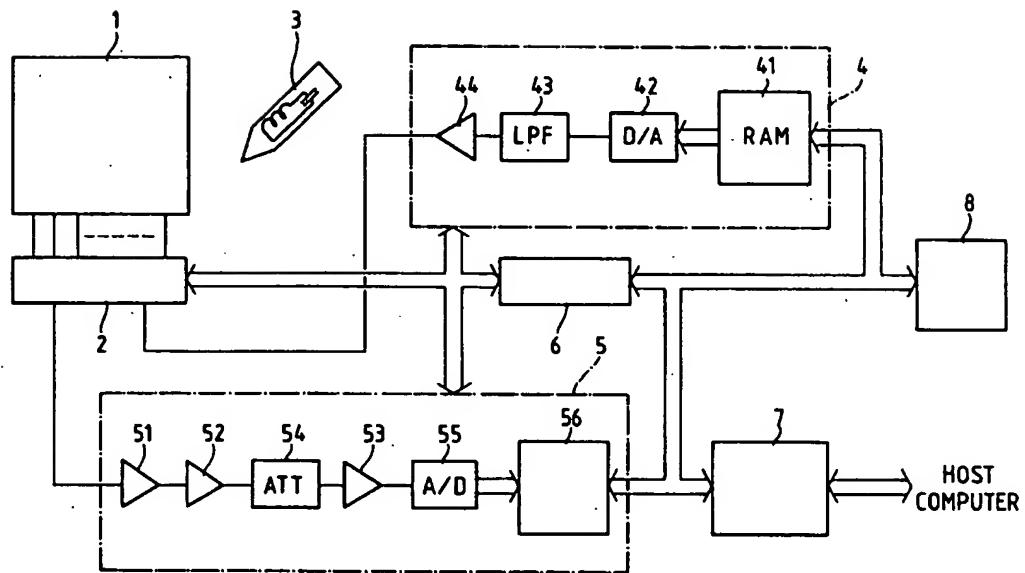
(74) Representative: TER MEER - MÜLLER -
STEINMEISTER & PARTNER
Mauerkircherstrasse 45
W-8000 München 80(DE)

(54) POSITION DETECTOR.

(57) A position detector which has a plurality of loop coils arranged in parallel with one another in the position detecting direction, and which is adapted to determine a coordinate value of position, which is designated by a position indicator having at least a coil, on the basis of the electromagnetic action between the position indicator and the position detector. One loop coil is selected simultaneously from each of a plurality of groups among a plurality of loop coils so that not less than a predetermined number of the relative positions of these selected loop coils do not become the same or symmetric in each group and over a plurality of groups. A loop coil on which the position indicator is positioned is determined among the loop coils on the basis of the pattern of a signal amplitude obtained by this loop coil selection. This makes it unnecessary to select all loop coils at the time of starting a position detecting operation, and serves to reduce the time required to determine the coordinate value. When the coordinate value is determined, the digital data corresponding to an arbitrary AC signal are converted into an analog signal, and a reception signal is sampled at a predetermined cycle to convert the signal into digital data. These digital data are subjected to predetermined computation to calculate amplitude and phase angle with respect to an arbitrary frequency component in the reception signal, whereby the concurrent use of a plurality of coordinate indicators is effected easily.

EP 0 499 641 A1

Fig. 1



FIELD OF THE INVENTION

This invention relates to a position detector which can shorten the time required to initially determine the position of a position indicator and which facilitates the simultaneous use of multiple position indicators, 5 in determining the coordinate values of the position specified by the position indicator(s).

BACKGROUND OF THE INVENTION

Prior to this application, the applicant submitted a proposal for a position detector to determine the 10 coordinate values of the position specified by the corresponding position indicator through transmission/reception of electromagnetic waves between a sensing unit and the position indicator under patent application No.S61-213970 (Refer to official gazette under patent disclosure No.S63-70326) (hereinafter referred to as the prior application).

The contents of the prior application will be briefly explained below. First, an electromagnetic wave is 15 generated by applying an AC signal to a loop coil in the sensing unit consisting of multiple loop coils juxtaposed in the direction of position detection. The tuning circuit incorporated in the position indicator is driven by this electromagnetic wave. At this time, an electromagnetic wave emitted from the tuning circuit is received by the said loop coil to generate an induced voltage. This is repeated on multiple loop coils in sequence. The amplitude and phase angle of the induced voltage generated at each loop coil or the 20 received signal are detected. With these values, the coordinate value of the specified position is determined.

However, in the above device, at least, all loop coils must be switched to determine the initial position 25 of the position indicator. This requires considerable detection time. In particular, a large sensing unit is required. That is, the device has the disadvantage of requiring more time as the number of loop coils increases.

To detect the amplitude and phase angle of the signal corresponding to the AC signal actually applied 30 to a loop coil from among received signals, the above device uses a ceramic filter which allows only the frequency component corresponding to the frequency of the AC signal to pass. Therefore, if two or more AC signals of different frequencies are used, ceramic filters corresponding to each frequency must be 35 provided. Thus, the device has the disadvantage that it is difficult to simultaneously use multiple position indicators to increase the number of AC signal frequencies.

Additionally, the transient response characteristics of the above ceramic filter are so poor that 35 transmission/reception of electromagnetic waves must be repeated several times for each loop coil to receive a stable output signal. Thus, the device has the disadvantage that the loop coil switching speed cannot be increased because it takes considerable time to select a loop coil.

Furthermore, the said ceramic filter includes a mechanical vibrator, is of a specific size, and requires 40 many analog switches for individual loop coils for loop coil switching. Thus, the device has the disadvantage that component installation area and height cannot be reduced and it is difficult to design the device in IC form.

40 Disclosure of the Invention

The primary objective of the present invention is to shorten the time required to initially determine the 45 position of the position indicator.

To achieve the primary objective of the invention, the position detector to determine the coordinate values of the position specified by a position indicator using electromagnetic effect between a sensing unit 50 consisting of multiple loop coils juxtaposed in the direction of position detection, and the position indicator having at least one coil comprising a selection means for selecting a loop coil from each of the multiple groups including the above multiple loop coils juxtaposed in series whereby the relative positions of selected coils are not identical or symmetrical in each group or between groups except those within a predetermined limit, and an identifying means for identifying the loop coil on which the position indicator is located among the multiple loop coils according to the pattern of the signal amplitude obtained by the above loop coil selection.

By the invention, because the positions of the loop coils simultaneously selected by the selection 55 means are not identical or symmetrical in each group and between groups except those within a predetermined limit, the pattern of the signal amplitude obtained by the position of the position indicator differs and the loop coil on which the position indicator is located is identified by the identifying means according to this pattern. Consequently, selection of all loop coils is not necessary at the start of detection

unlike previously, and the time required to initially determine the coordinate value of the position specified by the position indicator can be greatly shortened.

The second objective of the present invention is to permit the simultaneous use of multiple position indicators, freely setting the frequency, phase and amplitude of the AC signal to be used, without the necessity of changing hardware.

To achieve this, a position detector to determine the coordinate value of the position specified by a position indicator using electromagnetic effect between a sensing unit consisting of multiple loop coils juxtaposed in the direction of position detection and a position indicator having at least one coil possesses a data generating means for generating digital data corresponding to any AC signal, a digital-analog conversion means for converting this digital data into an analog signal, an analog-digital conversion means for converting a received signal into digital data sampling it within a predetermined period, and an arithmetic means for calculating the amplitude and phase angle for an optional frequency component in a received signal by performing a predetermined arithmetic operation for the digital data.

By the invention, the digital data generated by the data generating means is sent to the analog conversion means where it is converted into an ordinary analog AC signal. The frequency, phase and amplitude of this AC signal can be freely set using the digital data sent to the analog conversion means from the memory means. The received signal is converted into digital data by the analog-digital conversion means and an arithmetic operation based on the digital data is performed by the arithmetic means to calculate the amplitude and phase angle for an optional frequency component in the received signal.

Accordingly, electromagnetic waves of any frequency, phase and amplitude can be generated and the amplitude and phase angle for an optional frequency component can be detected. Also, multiple position indicators having a tuning circuit of a different tuning frequency or position indicators with multiple turning circuits of different turning frequencies can be used simultaneously and their positions can be detected immediately.

Also, the third objective of the present invention is to increase the loop coil switching speed and reduce the component installation area and height, or to make possible IC-format design, lower power consumption and cost reduction.

To achieve the third objective of the invention, a configuration is provided which requires no ceramic filter for the said position transducer. With this, it is sufficient to perform transmission/reception of electromagnetic waves only once for a loop coil, with the result that switching speed can be greatly improved and the number of analog switches can be reduced. Because multiple oscillators are not required, the component installation area and height can be reduced and the whole device can be designed in IC format except the sensing unit. Consequently, a small, low-power-consumption and low-cost device can be realized.

Other objects, constituents and effects than the above will be clarified in the following explanation.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 is a block diagram of this invention's position detector as a working example. FIG. 2 is a drawing showing a detailed configuration of the sensing unit and switching unit. FIG. 3 is a sectional view of the input pen. FIG. 4 is an explanatory drawing of DA converter conversion characteristics. FIG. 5 is an explanatory drawing of AD converter conversion characteristics. FIG. 6 is a flowchart of processing in the processing unit. FIG. 7 is a flowchart of processing in the control unit. FIG. 8 (a) and (b) are wave-form charts of PAM signal and its envelope component in the signal generating unit. FIG. 9 (a) and (b) are waveform charts that indicate an example of a transmitting signal and received signal. FIG. 10 (a), (b) and (c) are diagrams showing changes in received signal when loop coils are switched in turn. FIG. 11 (a) and (b) are diagrams showing changes in received signal when loop coil switching is performed according to each input pen position. FIG. 12 is a drawing showing sampling number positions for a received signal. FIG. 13 (a) and (b) are drawings showing the positional relation between the input pen and loop coils. FIG. 14 (a), (b) and (c) are waveform charts showing a part of PAM signal when the phase is shifted. FIG. 15 (a) and (b) are waveform charts showing other examples of PAM signal. FIG. 16 (a) and (b) are waveform charts showing still further examples of PAM signal.

EMBODIMENT OF THE INVENTION

55

FIG. 1 shows an example of the present invention's position detector in operation. In the figure, 1 is a sensing unit, 2 is a switching unit, 3 is a position indicator, 4 is a signal generating unit, 5 is a signal detecting unit, 6 is a control unit, 7 is an interface unit, and 8 is a processing unit.

FIG. 2 shows details of sensing unit 1 and switching unit 2. In the figure, 11-0 to 11-23 are loop coils, and 21, 22, 23 and 24 are analog switches.

Individual loop coils 11-0 to 11-23 are roughly rectangular and juxtaposed in such a way that the longer sides intersect orthogonally in the direction of position detection, for example, in the X-direction. Above loop coils 11-0 to 11-23 comprise three groups I, II and III including 8 loop coils juxtaposed in series. That is, group I consists of loop coils 11-0 to 11-7, group II consists of loop coils 11-8 to 11-15, and group III consists of loop coils 11-16 to 11-23. The ends of individual loop coils in groups I, II and III are connected to the 8 selection terminals of analog switches 21, 22 and 23, and their other ends are grounded in common. The switching terminals of analog switches 21, 22 and 23 are connected to the switching terminal 5 of analog switch 24 in common. The two selection terminals of analog switch 24 are connected to signal generating unit 4 and signal detecting unit 5 respectively. Analog switches 21 to 24 are designed in such a way that the switching terminals can be connected to a selection terminal according to the information sent from control unit 6. The number of loop coils and the number of groups in above complete sensing unit 1 and the number of loop coils in each group are only provided as an example and are not limited to this. The 10 number of loop coils comprising each group may be not equal.

Here, loop coils 11-0 to 11-7 of group I are connected to the selection terminals of analog switch 21 in the order of terminal numbers, namely, "0, 1, 2, 3, 4, 5, 6, 7". However, loop coils 11-8 to 11-15 of group II are connected to the selection terminals of analog switch 22 in the order of terminal numbers "0, 2, 1, 4, 3, 6, 5, 7" and loop coils 11-16 to 11-23 of group III are connected to the selection terminals of analog switch 15 23 in the order of terminal numbers "2, 0, 4, 1, 6, 3, 7, 5". This aims at preventing the relative positions of the loop coils to be simultaneously selected by analog switches 21, 22 and 23 from being identical or symmetrical in each group and between groups except those within a predetermined limit, or up to 3 loop coils in this case. That is, supposing that the loop coils connected to selection terminal numbers "0, 1, 2, 3, 4, 5, 6, 7" of each analog switch are " $C_0, C_1, C_2, C_3, C_4, C_5, C_6, C_7$ ", the relative position (array) for 20 example, of " C_0, C_1, C_2, C_3 " does not exist in the other groups or between two groups and the array of " C_3, C_2, C_1, C_0 " does not exist, either.

Position indicator 3 (hereinafter referred to as the input pen) contains a ball pen tip 32, a ferrite core 33 featuring a through hole to freely allow tip 32 to be slid in, a coil spring 34, and a tuning circuit 35 consisting of a switch 351, a coil 352 wound around ferrite core 33 and capacitors 353 and 354 combined in 30 a unit in a case 31 made of a nonmetallic material such as resin from its front end in this order, as shown in FIG. 3. A cap 36 is provided at its rear end.

Above coil 352 and capacitor 353 are mutually connected in series to provide a standard resonance circuit configuration. The values of coil 352 and capacitor 353 are set at the values where the predetermined frequency f_0 is a resonance (tuning) frequency. Capacitor 354 is connected in parallel across 35 capacitor 353 through switch 351, and acts to reduce (lower) the said resonance frequency when switch 351 is turned on. By pushing the end of tip 32 against the input surface (not shown in the figure) of sensing unit 1 while holding case 31 by hand so that it may be inserted into the case 31, switch 351 is pushed from the rear through coil spring 34, and is thereby turned on.

Signal generating unit 4 consists of a random access memory (RAM) 41, a digital-analog converter (DA 40 converter) 42, a low pass filter (LPF) 43 and a driving amplifier 44, and generates AC signals with an optional frequency, phase and amplitude.

RAM 41 stores the data corresponding to an AC signal to be generated out of multiple-bit data, or 6-bit digital data in this case, corresponding to the optional signals previously prepared in processing unit 8 or the host computer. DA converter 42 converts the digital data read out from RAM 41 into analog pulse (PAM) 45 signals in sequence. FIG. 4 shows conversion characteristics in DA converter 42. Low pass filter 43 removes a high-frequency component from the above PAM signal and outputs only its envelope component. Driving amplifier 44 amplifies the above envelope component to a proper level and outputs it as a target AC signal. Data writing and data reading in above RAM 41 and conversion in DA converter 42 are executed according to the information from control unit 6. A read-only memory storing the digital data 50 corresponding to at least one AC signals may be used in place of RAM 41. If a high-speed CPU is used for processing unit 8, a bus buffer may be used.

Signal detecting unit 5 consists of a preamplifier 51, amplifiers 52 and 53, an attenuator (ATT) 54, an analog-digital converter (AD converter) 55 and an arithmetic circuit 56, and detects the amplitude and phase angle for an optional frequency component in a received signal.

Preamplifier 51, amplifiers 52 and 53 and attenuator 54 amplify a received signal to a proper level. AD converter 55 samples the amplified received signal within a predetermined period or 250 nsec in this case, and converts it into 6-bit digital data. FIG. 5 shows conversion characteristics in AD converter 55. Arithmetic circuit 56 performs a predetermined arithmetic operation, for example, a discrete Fourier transform

operation that will be described later, by using the above digital data to calculate the amplitude and phase angle for an optional frequency component. The attenuation adjustment in above attenuator 54, the conversion in the AD converter 55 and the calculation in arithmetic circuit 56 are executed according to the information from control unit 6.

5 Control unit 6 operates on the basis of instructions from processing unit 8 to control the timing of each unit according to the preset sequence. To reduce the power consumption, signal detecting unit 5 enters a standby state when an electromagnetic wave is generated (transmitted) and signal generating unit 5 enters a standby state when an electromagnetic wave is received. If no received signal can be obtained after a certain time has elapsed, or if no position indicator is detected, both signal generating unit 4 and signal 10 detecting unit 5 enter a standby state.

Interface unit 7 undertakes data exchange with the host computer and consists of at least two registers directly connected to the bus line of the host computer. The register is of FIFO memory structure. The host computer reads out data according to a determined data format by accessing this register several times.

15 Processing unit 8 calculates the coordinate values of a specified position, performs data transmission with the host computer, and exerts overall unit control. This unit consists of a well-known microprocessor, ROM and RAM storing necessary programs and data, etc.

FIG. 6 represents a flowchart of processing in processing unit 8. In the following, the operations of this device will be explained according to this flowchart.

First, processing unit 8 resets each unit (S1) and writes the digital data corresponding to a sine wave 20 signal of frequency f_0 previously prepared in RAM 41 of signal generating unit 4 or of 500 kHz in this case (S2). More precisely, the processing unit writes 128 6-bit digital data representing a 500 kHz 16-wave sine wave signal that can be output within a predetermined transmission period or 32 μ sec in this case. Next, processing unit 8 writes switching data into control unit 6 to switch analog switches 21 to 23 in the order of terminals numbers "0, 1, 2, 3, 4, 5, 6, 7" (S3), and causes control unit 6 to perform transmission/reception 25 of electromagnetic waves (S4).

FIG. 7 represents a flowchart of processing in control unit 6 concerned in the said transmission/reception of electromagnetic waves. First, control unit 6 outputs data to select the initial data, or terminal number 0 in this case, to analog switches 21 to 23 (sp1) to start signal generating unit 4, and outputs data to select this signal generating unit side to analog switch 24 (sp2). Next, control unit 6 transfers 30 the digital data in RAM 41 in sequence to the DA converter by supplying clocks and causes it to execute DA conversion to convert this digital data into a PAM signal (sp 3).

FIG. 8(a) shows the PAM signal that is output by the above DA converter at this time. This PAM signal is converted into an envelope component as shown in FIG. 8 (b), or a 500 kHz AC signal, by removing the high-frequency component through low pass filter 43 as previously described. Then, this signal is amplified 35 to a proper level by driving amplifier 44 and output to switching unit 2.

The above PAM signal is actually a unipolar signal consisting of only a positive component and a negative component. In the drawing, the signal is represented as a bipolar signal to facilitate understanding. (The DC part is actually cut off by low pass filter 43 or driving amplifier 44 or a capacitor inserted between them which is not indicated in the drawing, with the result that the signal becomes a bipolar signal.)

40 The above AC signal passes through analog switch 24 and is supplied to loop coils C_0 in the sensing unit, selected by each of analog switches 21 to 23, namely, 11-0, 11-8 and 11-17. The signal is emitted as an electromagnetic wave.

At this time, when input pen 3 is held in an approximately upright state or an operational state, on 45 sensing unit 1, this electromagnetic wave drives coil 352 of input pen 3 and causes tuning circuit 35 to generate an induced voltage synchronized with the above AC signal.

On the other hand, when the above transmission period of 32 μ sec terminates, control unit 6 puts signal generating unit 4 into a standby state and starts signal detecting unit 5, and outputs data to select this signal detecting unit side to analog switch 24 (sp4).

When analog switch 24 is switched, the electromagnetic wave from loop coils 11-0, 11-8 and 11-17 50 disappears immediately. However, the induced voltage generated in tuning circuit 35 of input pen 3 is gradually attenuated according to its loss and causes coil 352 to emit an electromagnetic wave. This electromagnetic wave reverse-drives loop coils 11-0, 11-8 and 11-17 connected to signal detecting unit 5 through analog switch 24, so that induced voltage (received signal) due to the electromagnetic wave from coil 352 is generated at loop coils 11-0, 11-8 and 11-17. FIG. 9 (a) and (b) show an example of transmitting 55 signal and received signal waveforms in sensing unit 1.

The above received signal is amplified to a proper level by preamplifier 51, amplifiers 52 and 53 and attenuator 54 and then input into the AD converter 55.

After starting the signal detecting unit, control unit 6 supplies clock control to cause AD converter 55 to

sample the received signal 128 times at intervals of 250 nsec to execute AD conversion and causes arithmetic circuit 56 to perform a discrete Fourier transform operation that will be described later (sp5), and outputs its result to processing unit 8 (sp6). The time (32 μ sec) required to sample the above received signal 128 times at intervals of 250 nsec is called the receiving period.

5 Next, control unit 6 has the switching data for analog switches 21 to 23 updated into second data, or data to select terminal number "1" in this case, and has above steps sp1 to sp6 executed. After obtaining the results of calculations for loop coils C₁, namely, 11-1, 11-10 and 11-19, the control unit sends them out to processing unit 8. Thus, the switching data is updated up to the 8th data and the above operations are repeated (sp7 and sp8).

10 Regarding the amplitude out of the said calculation results, the values obtained by switching analog switches 21 to 23 vary with the X-direction positions of input pen 3.

FIG. 10 (a) shows an example of changes of the amplitude (level) of a received signal obtained by switching analog switches 21 - 23 when input pen 3 is on position A or loop coil 11-4 in FIG. 2. In the figure, S₀, S₁, S₂, S₃, S₄, S₅, S₆ and S₇ represent the timing at which each of the selection terminals with terminals numbers "0, 1, 2, 3, 4, 5, 6, 7" is selected in analog switches 21 to 23, and e₀, e₁, e₂, e₃, e₄, e₅, e₆ and e₇ represent the levels corresponding to the above timing. FIG. 10 (b) is the same type of drawing as FIG. 10 (a) when input pen 3 is on position B or loop coil 11-11 in FIG. 2. FIG. 10 (c) is the same type drawing as FIG. 10 (a) when input pen 3 is on position C or loop coil 11-18 in FIG. 2.

15 Due to the said relative positional relation of each loop coil in sensing unit 1, the pattern of received signal level change in FIG. 10 (b) or (c) is different from the case shown in FIG. 10 (a). This pattern differs with each loop coil on which input pen 3 is located and can be determined uniquely by it.

20 For example, when e₄ > e₃ > e₅ > e₂,
or e₄ > e₃ = e₅ > e₂ (= e₆),
or e₄ > e₅ > e₃ > e₆,

25 input pen 3 is located on coil 11-4.

When

e₄ > e₁ > e₃ > e₂,
or e₄ > e₁ = e₃ > e₂ (= e₆),
or e₄ > e₃ > e₁ > e₆,

30 input pen 3 is located on loop coil 11-11.

When

e₄ > e₀ > e₁ > e₂,
or e₄ > e₀ = e₁ > e₂ (= e₆),
or e₄ > e₁ > e₀ > e₆,

35 input pen 3 is located on the loop coil 11-18.

Processing unit 8 pre-registers each pattern to be obtained when input pen 3 is located on each of loop coils 11-0 to 11-23, and identifies the nearest loop coil or the loop coil on which input pen 3 is located, by the pattern obtained as a result of the processing of above step S4 (S5).

40 Incidentally, in this device, the final coordinate values are calculated by an interpolation operation based on the received signal levels obtained from the nearest loop coil and the loop coils provided on both sides of it as described later. Therefore, it is desirable to obtain each received signal with the pattern (single peak response) shaped as shown in FIG. 10 (a). To attain this, it is sufficient to change the loop coil switching order according to the loop coil closest to input pen 3.

45 For example, when input pen 3 is located on said position B, analog switches 21 to 23 are switched in the order of terminal numbers "0, 2, 1, 4, 3, 6, 5, 7", so that a received signal level with a single peak response such as shown in FIG. 11 (a) can be obtained. When input pen 3 is located on position C, analog switches 21 to 23 are switched in the order of terminal numbers "7, 2, 0, 4, 1, 6, 3, 7", so that such a received signal with a single peak response as shown in FIG. 11 (b) can be obtained.

50 Processing unit 8 pre-registers the analog switch switching orders that permit the said received signal level with a single peak response to be obtained for the case where input pen 3 is located on each of loop coils 11-0 to 11-23, and writes analog switch 21 - 23 switching data corresponding to the loop coil closest to input pen 3, obtained as a result of the processing of above step S5, into control unit 6 (S6), and causes control unit 6 to perform transmission/reception of electromagnetic waves in the same way as above step S4 (S7).

55 Processing unit 8 checks if the pattern of the received signal level obtained from the result of the processing of above step S7 is of a single peak response (S8), and repeats the processing of S3 to S7 if it is not. If the single peak response is obtained, processing unit 8 calculates the coordinate value and phase information of the position specified by input pen 3 from the result obtained at that time as described later

(S9), writes them onto interface unit 7 (S10), and transfers them to the host computer. After that, the processing of steps S6 to S10 is repeated.

Next, the discrete Fourier transform operation in arithmetic circuit 56 of signal detecting unit 5 and the result to be obtained thereby, will be explained.

- 5 Supposing that the data sampled in a predetermined period (250 nsec in this case) and then converted into a digital value in the AD converter 55 is v_i (i : sampling number), the transformation value V_k corresponding to the frequency component, represented by the number k of waves insertable in the receiving period, is represented as follows:

$$10 \quad V_k = (1/N) \sum_{i=1}^N v_i e^{-j\{2\pi(i-1)K/N\}} \quad \dots \quad (1)$$

- 15 In the above, N is the number of sampling times, namely, 128 in this case. k is an integer $0 - (N - 1)$, namely, $0 - 127$. Sampling number i is $1 - 128$. The position for the received signal is shown in FIG. 12.

The wave length corresponding to 2π in the above expression (1) is 32 sec, namely, 31.25 kHz. Accordingly, V_k at $k = 0$ represents the DC component. V_k at $k = 1$ represents the frequency component of 31.25 (kHz) $\times 1 = 31.25$ kHz. V_k at $k = 2$ represents the frequency component of 31.25 (kHz) $\times 2 = 62.5$ kHz. Thus, V_k at $k = 16$ represents the frequency component of 31.25 (kHz) $\times 16 = 500$ kHz.

20 Accordingly, by obtaining the k value corresponding to the frequency component of the transmitting signal or 500 kHz, namely, by obtaining V_k at $k = 16$, the received signal corresponding to the electromagnetic wave emitted from input pen 3 can be output.

Now, complex number calculation can be represented as follows:

$$25 \quad e^{j\theta} = \cos \theta - j \sin \theta \quad (2)$$

That is, as the real part is real ($e^{j\theta}$) = $\cos \theta$ and the imaginary part is image ($e^{j\theta}$) = $-\sin \theta$, the real part in the above expression (1) is represented as:

$$30 \quad A_k = (1/N) \sum_{i=1}^N v_i \cos(2\pi(i-1)K/N) \quad \dots \quad (3)$$

- 35 The imaginary part is also represented as:

$$40 \quad B_k = (1/N) \sum_{i=1}^N v_i \sin(2\pi(i-1)K/N) \quad \dots \quad (4)$$

Consequently,

$$45 \quad V_k = (A_k^2 + B_k^2)^{1/2} \quad (5)$$

Actually, the amplitude of the received signal can be obtained by calculating expressions (3), (4) and (5). The phase angle of the received signal can be obtained by the following expression.

$$50 \quad \theta_k = \tan^{-1}(B_k/A_k) \quad (6)$$

- If two or more frequency components are mixed in a transmitting signal and two or more input pens provided with a tuning circuit for these frequencies or an input pen provided with two or more tuning circuits for these frequencies is used as described later, it is sufficient to determine V_k and θ_k of the k values corresponding to individual frequencies.

55 Next, the calculation of the coordinate value and phase information of a specified position in processing unit 8 will be explained.

Supposing that the level of the received signal obtained from the loop coil closest to the position of

input pen 3 is E_0 and the levels of the received signals obtained from the adjacent loop coils are E_1 and E_2 ($E_0 > E_1 > E_2$) respectively, the relation between position X_c of input pen 3 and the position of each loop coil is as shown in FIG. 13 (a) or (b). In this case, X_n is the center position of the loop coil with coil number n closest to input pen 3, X_{n-1} is the center position of the loop coil with coil number $(n - 1)$, and X_{n+1} is the center position of the loop coil with coil number $(n + 1)$. The above coil numbers mean the numbers in the case where loop coils are counted to the right, assuming that the far left loop coil is the first loop coil.

In the case of FIG. 13 (a), namely, where level E_1 corresponds to the $(n - 1)$ th loop coil, coordinate value X_c of input pen 3 with X_0 (left end of loop coil 11-0) as the origin can be found by the following expression assuming that the pitch between loop coils is P .

$$10 \quad X_c = (n-1)P + (E_0-E_1)/(2E_0-E_1-E_2)P + P/2 \quad (7)$$

In the case of FIG. 13 (b), namely, where level E_1 corresponds to the $(n + 1)$ th loop coil, coordinate value X_c can be found similarly by the following expression.

$$15 \quad X_c = (n-1)P + (E_0-E_2)/(2E_0-E_1-E_2)P + P/2 \quad (8)$$

Accordingly, processing unit 8 receives above E_0 , E_1 and E_2 from the received signal amplitude obtained by signal detecting unit 5, judges whether E_1 corresponds to the $(n - 1)$ th loop coil or the $(n + 1)$ th loop coil, and determines the coordinate value X_c by performing calculation of expression (7) or (8).

The phase information of the input pen means a difference in phase angle between the transmitting signal and received signal caused by a slight shift of tuning frequency in the tuning circuit. In this case, because the phase angle of the transmitting signal is set at 0° , the phase angle θ_k of the received signal determined by signal detecting unit 5 is used as it is.

25 Because the tuning frequency of tuning circuit 35 is changed when switch 351 of input pen 3 is turned on and off as previously described, the above phase information is also changed when switch 351 is turned on and off. Accordingly, the on or off state of above switch 351 can be detected from changes in this phase information (for example, in the host computer). The on (or off) state of switch 351 is used as information to specify a value for actual input, out of the coordinate values of the specified positions, by input pen 3.

30 In the above embodiment, it is sufficient to switch the loop coils of the sensing unit 1 eight times from the start of measurement. So, the time required to first determine the position of input pen 3 can be greatly reduced. Generally, supposing that the number of groups in the said sensing unit is m , the time required is $1/m$ of the time for selecting all loop coils in sequence. In the above operational example, analog switches are provided in accordance with the loop coils in each group. However, loop coils to be simultaneously selected in each group may be connected before connection to the analog switch. In this case, the use of one analog switch is sufficient. In this case, nine wires, including grounding wire, between the sensing unit and the switching unit are sufficient. Thus, the sensing unit can be installed on a different board separately from the other parts, for example, on a film board on which parts cannot be soldered. This leads to cost reduction of the sensing unit.

40 In the above embodiment, the frequency, phase and amplitude of an electromagnetic wave to be generated from the loop coil can be freely set by the digital data to be written into RAM 41 of signal generating unit 4. Even when an electromagnetic wave of two or more frequencies is generated, an oscillator for each frequency is not required and the amplitude and phase angle for an optional frequency component can be calculated by applying a Fourier transform operation to a received signal by arithmetic circuit 56 of signal detecting unit 5. Accordingly, when an electromagnetic wave of two or more frequencies is generated, the amplitude and phase angle of each frequency can be precisely calculated. As no ceramic filter is required unlike previously, it is sufficient to perform the transmission/reception of electromagnetic waves only once for a loop coil. This greatly improves switching speed and permits complete design in IC format except the sensing unit, resulting in a cost reduction.

45 In the above embodiment, signal detecting unit 5 enters a standby state while an electromagnetic wave is transmitted, and signal generating unit 4 enters a standby state while an electromagnetic wave is received. This contributes to reduction in power consumption. In the above embodiment, the coordinate values of a specified position only in the X-direction or only in one direction is detected.

50 However, if another sensing unit similar to sensing unit 1 is juxtaposed in close vicinity at a right angle to sensing unit 1, and a switching unit similar to switching unit 2 is connected to it, a switching circuit is provided between these two switching units and between signal generating unit 4 and signal detecting unit 5, and a slight change occurs in the programs of control unit 6 and processing unit 8. The coordinate value of a specified position in both X and Y directions can thus be detected.

In the above embodiment, the configuration of sensing unit 1, switching unit 2 and the loop coil switching control based thereon, and signal processing by signal generation unit 4 and signal detecting unit 5 do not always need to be performed simultaneously. A standard sensing unit and switching unit may be combined with above signal generating unit 4 and signal detecting unit 5. Or, above sensing unit 1 and switching unit 2 and the loop coil switching control based thereon may be combined with an ordinary signal generating unit and signal detecting unit.

FIG. 14 shows a part of the PAM signal output from D converter 42 when the phase of the transmission signal is shifted. FIG. 14 (a) is the signal output with 0° phase. FIG. 14 (b) is the signal output with 45° phase. FIG. 14 (c) is the signal output with 90° phase. Because a large counter electromotive force is caused if a large current is suddenly connected to or disconnected from loop coils which may destroy electronic parts, a transmission signal with only one frequency component is never output with a phase other than 0°.

FIG. 15 shows another example of the PAM signal output from DA converter 42. FIG. 15 (a) shows the signal corresponding to a transmission signal with a frequency of 437.5 kHz (14 waves in the transmission period of 32 μsec) and FIG. 15 (b) shows the signal corresponding to a transmission signal with a frequency of 375 kHz (12 waves in the transmission period of 32 μsec).

FIG. 16 shows another example of PAM signal output from the DA converter. FIG. 16 (a) shows a composite signal consisting of a transmission signal with a frequency of 500 kHz and a transmission signal with a frequency of 437.5 kHz, and FIG. 16 (b) shows a composite signal consisting of a 500 kHz transmission signal, a 437.5 kHz transmission signal and a 375 kHz transmission signal. All the above signals to be mixed have a phase angle of 0° and an amplitude of 1/2 in FIG. 16 (a) and an amplitude of 1/3 in FIG. 16 (b). In this case, if the signal shown in FIG. 16 (a) or (b) is directly output, a large current will be suddenly connected or disconnected as described before. For this reason, the signal is actually output from the position (P, Q in the figure) of 0° phase angle therein. (In this case, phase information is obtained for each frequency as the difference between the phase angle for positions P or Q and the phase angle of received signal.)

In the above explanation, the device to determine the coordinate values of the specified position by sending electromagnetic waves back and forth between the loop coils of the sensing unit and position indicator provided with a tuning circuit, has been described. However, this invention is applicable to any device if it determines the coordinate values of a specified position using electromagnetic effect between the loop coils of the sensing unit and the coil of the position indicator.

Claims

- 35 1. A position detector for determining the coordinate values of a position specified by a position indicator using electromagnetic effect between a sensing unit consisting of multiple loop coils juxtaposed in the direction of position detection, and the position indicator having at least one coil, comprising a selection means for simultaneously selecting a loop coil from each of the multiple groups including loop coils juxtaposed in series out of said multiple coils whereby the relative positions of selected coils are not identical or symmetrical in each group or between groups except those within a predetermined limit, and an identifying means for identifying the loop coil on which the position indicator is located among multiple coils according to the pattern of the signal amplitude obtained by said loop coil selection.
- 40 2. A position detector for determining the coordinate values of a position specified by a position indicator using electromagnetic effect between the sensing unit consisting of multiple loop coils juxtaposed in the direction of position detection and the position indicator having at least one coil, comprising a data generating means for generating the digital data corresponding to an optional AC signal, an digital-analog conversion means for converting this digital data into an analog signal, an analog-digital conversion means for converting a received signal into digital data after sampling within a predetermined period, and an arithmetic means for calculating the amplitude and phase angle for an optional frequency component in the received signal by performing a predetermined operation for digital data.
- 45 3. A position detector for determining the coordinate values of a position specified by a position indicator using electromagnetic effect between the sensing unit consisting of multiple loop coils juxtaposed in the direction of position detection and the position indicator having at least one coil, comprising a selection means for simultaneously selecting a loop coil from each multiple group including loop coils juxtaposed in series out of the above multiple loop coils whereby the relative positions of selected coils are not identical or symmetrical in each group or between groups except those within a predetermined limit, an

- identifying means for identifying the loop coil on which the said position indicator is located among multiple loop coils according to the pattern of the signal amplitude obtained by said loop coil selection, a data generating means for generating the digital data corresponding to an optional AC signal, a digital-analog conversion means for converting this digital data into an analog signal, an analog-digital conversion means for converting a received signal into digital data while performing sampling within a predetermined period, and an arithmetic means for calculating the amplitude and phase angle for an optional frequency component in the received signal by performing a predetermined operation for this digital data.
- 5 4. A position detector according to Claims 2 or 3 wherein said optional AC signal is composed of at least two signals with different frequencies.
- 10 5. A position detector according to Claims 2, 3 or 4 wherein said predetermined operation is a discrete Fourier transform operation.
- 15 6. A position detector according to any of Claims 1 to 5, featuring a means for detecting the coordinate values of a specified position for two directions of position detection that orthogonally intersect.

20

25

30

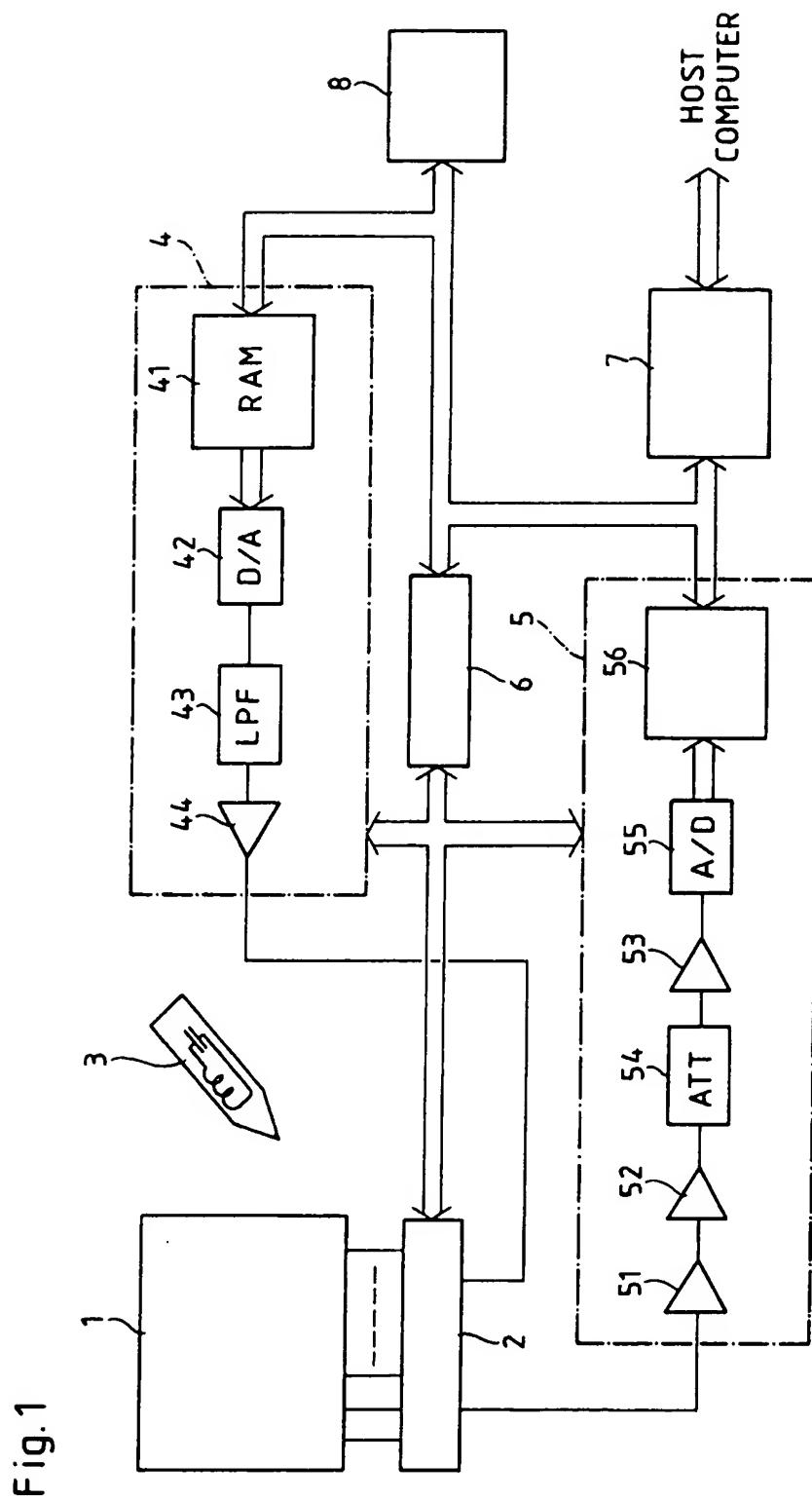
35

40

45

50

55



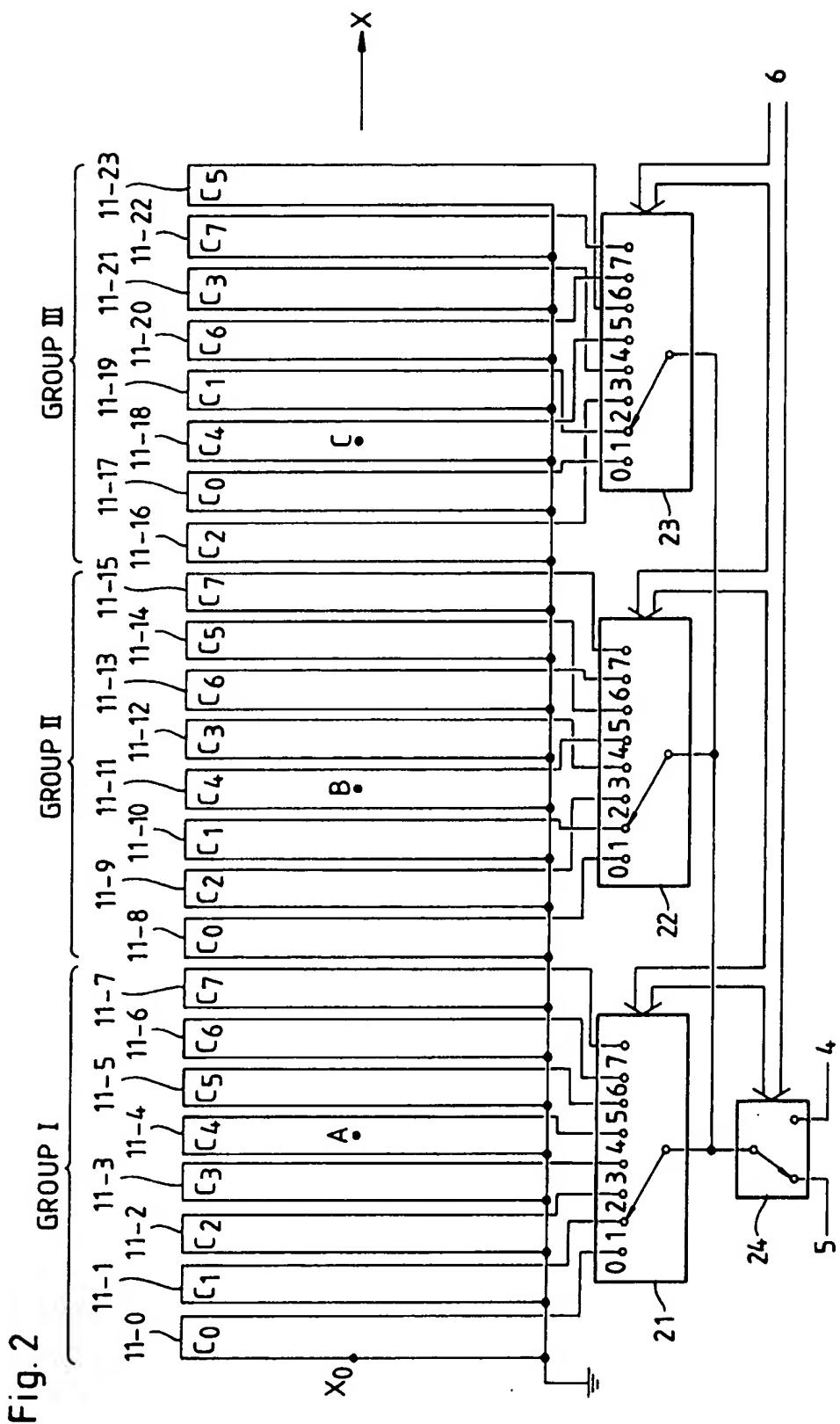


Fig. 3

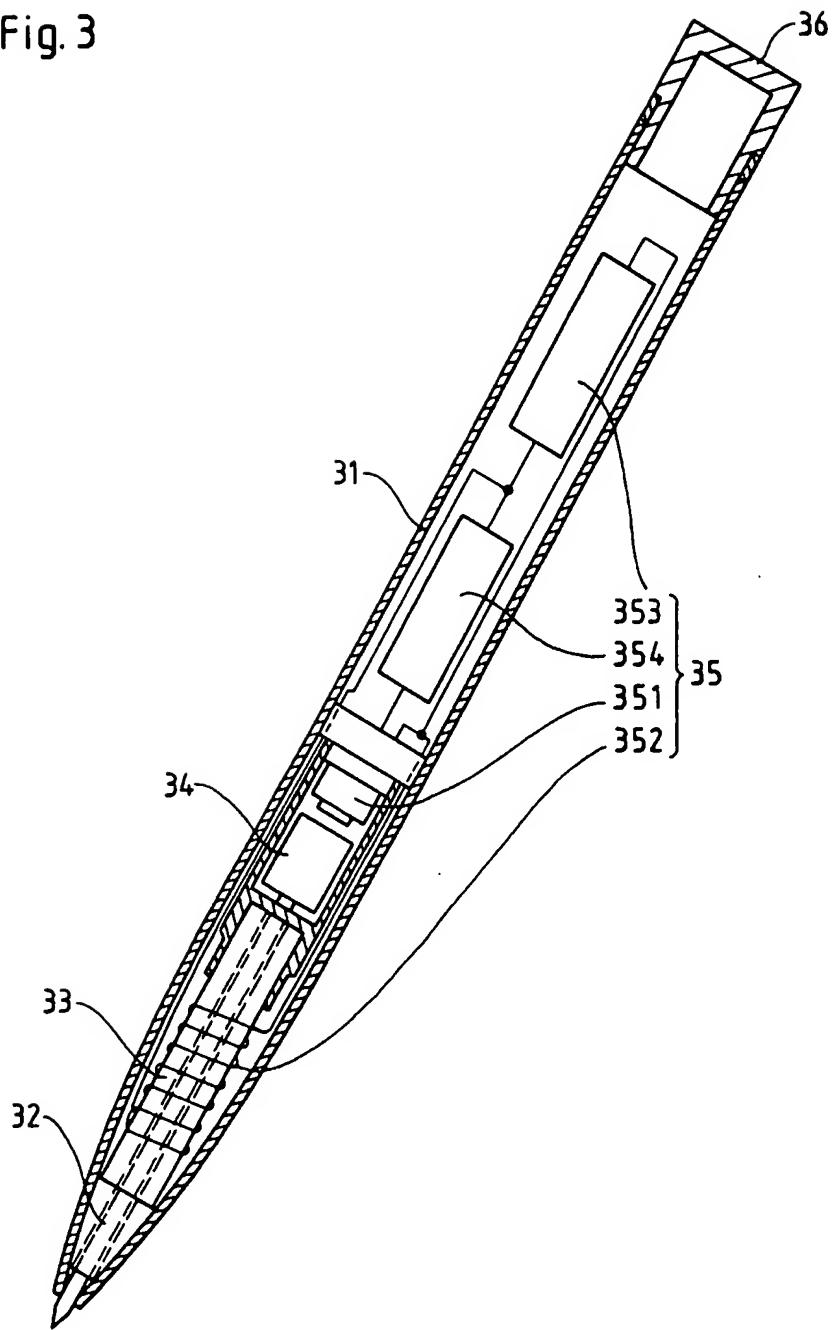


Fig. 4

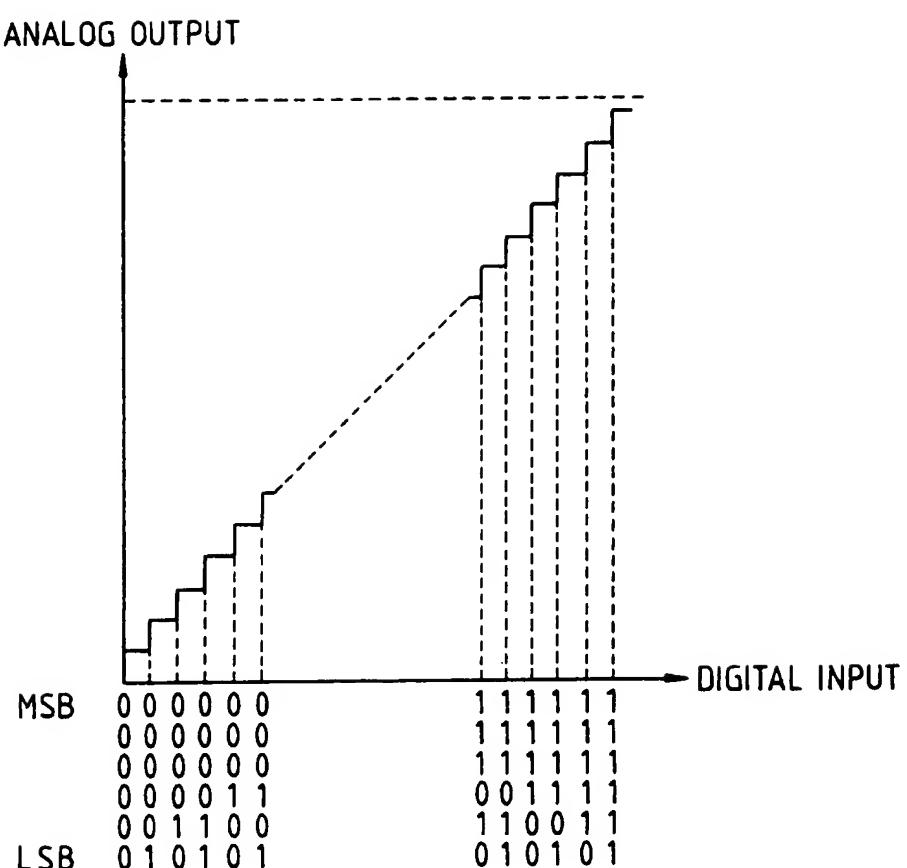


Fig. 5

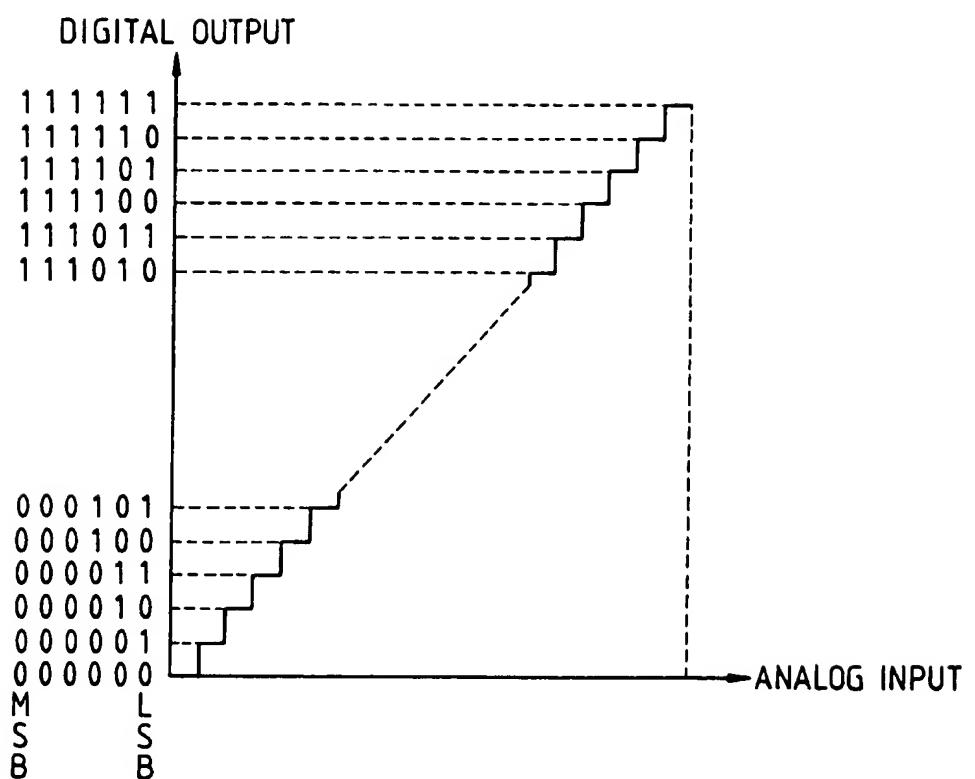


Fig. 6

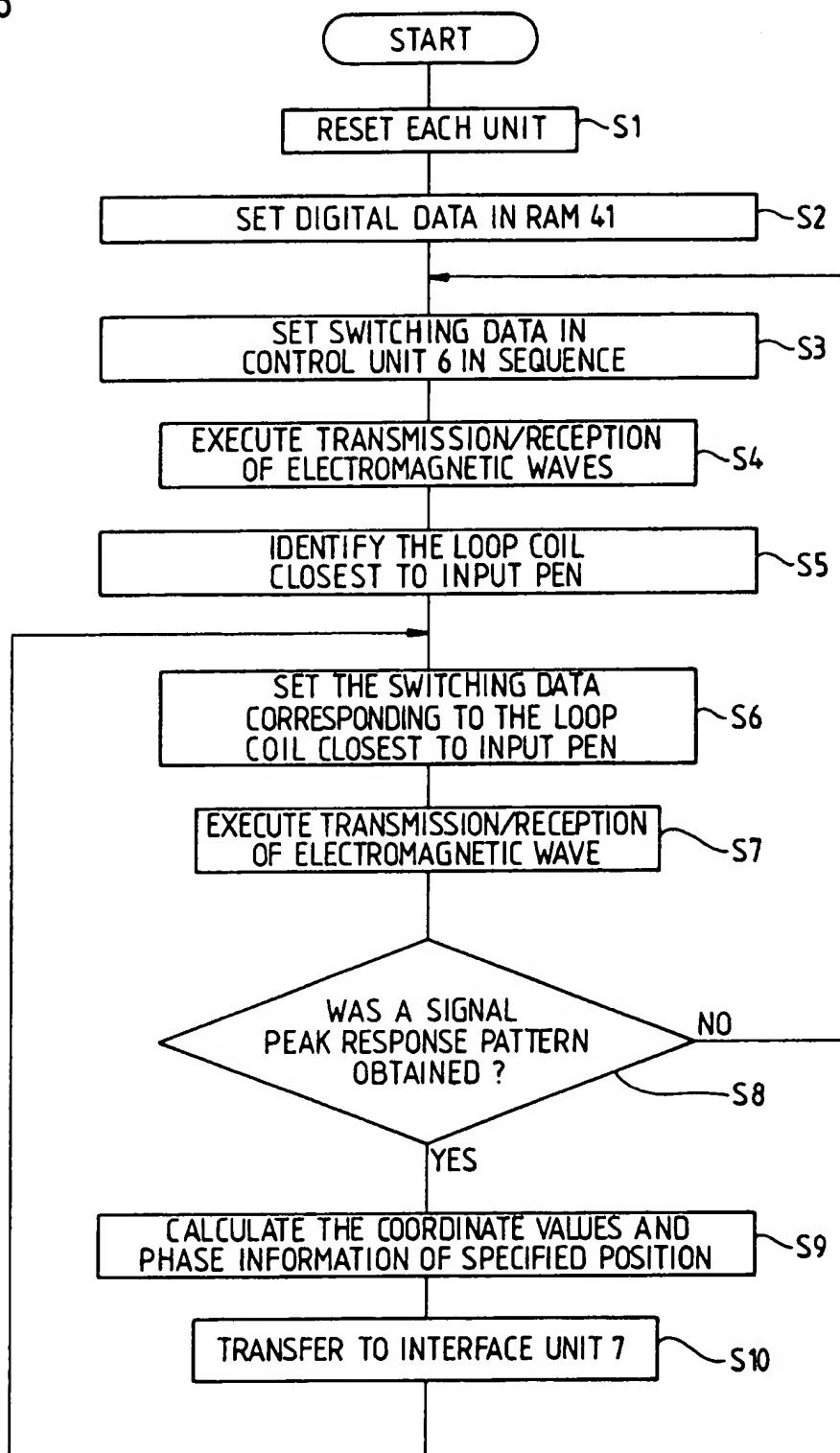


Fig.7

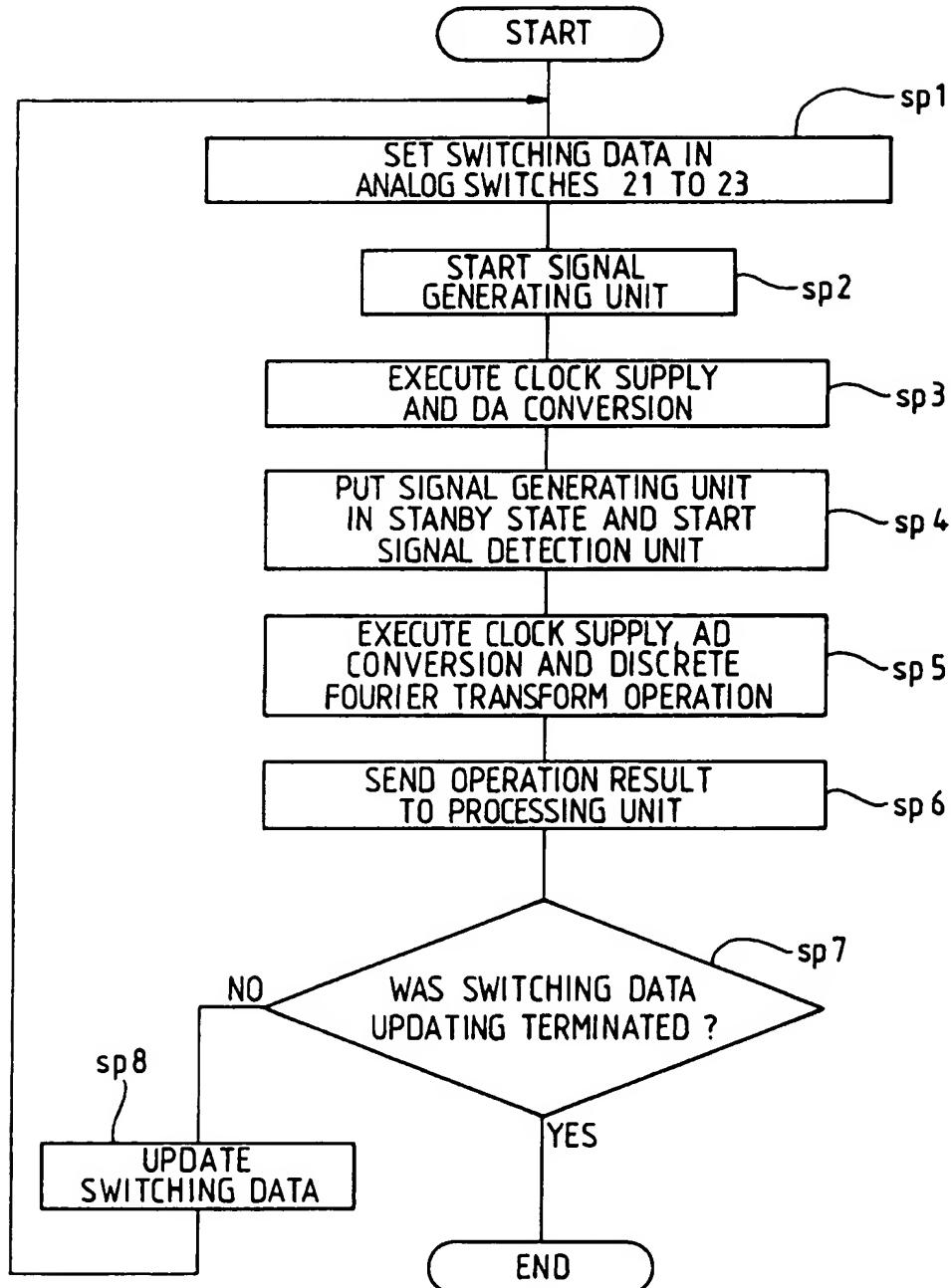


Fig. 8

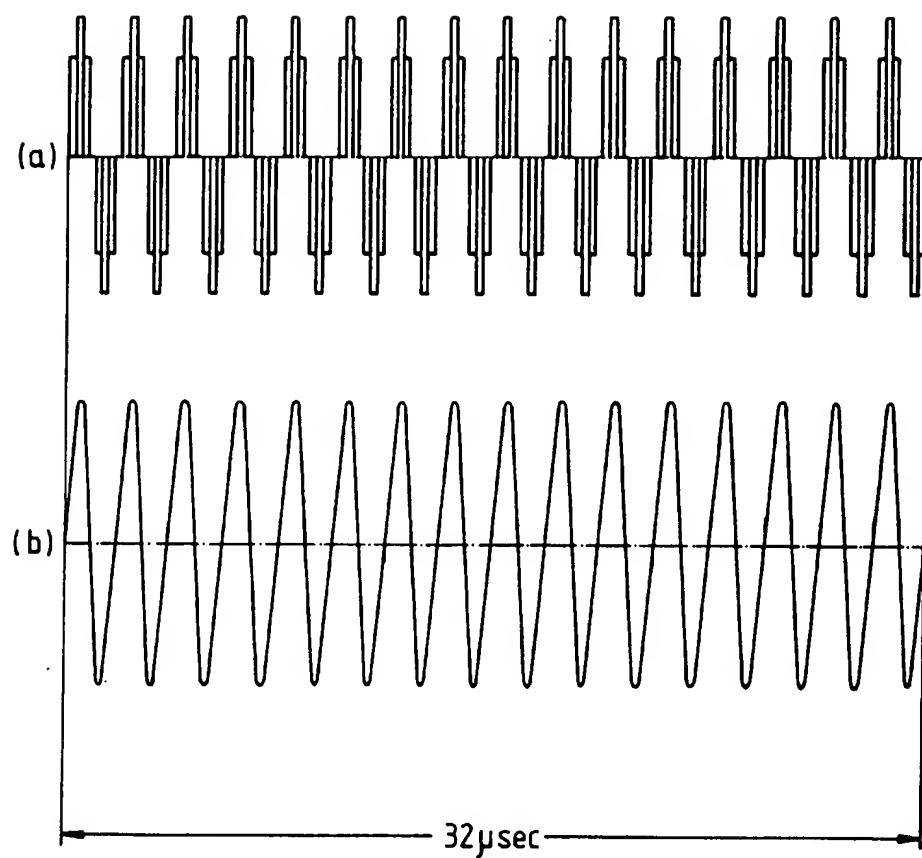


Fig. 9

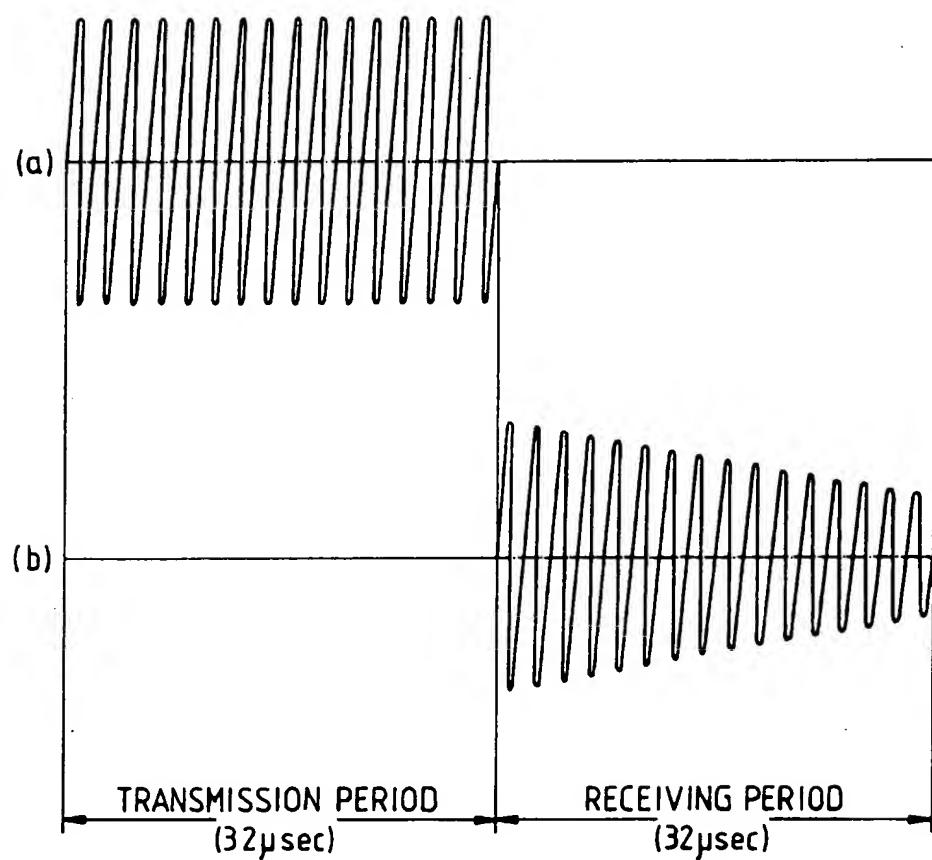


Fig.10

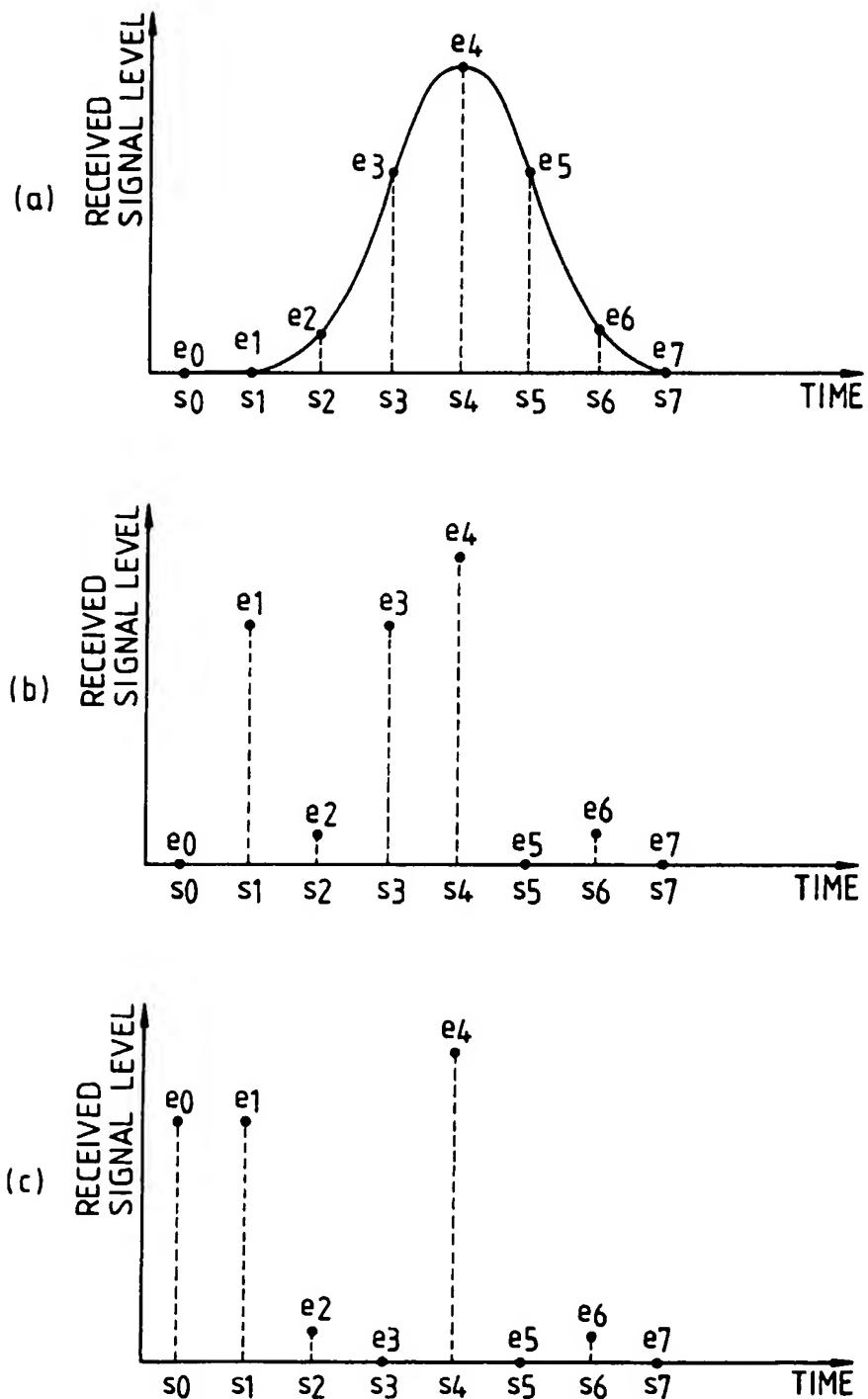
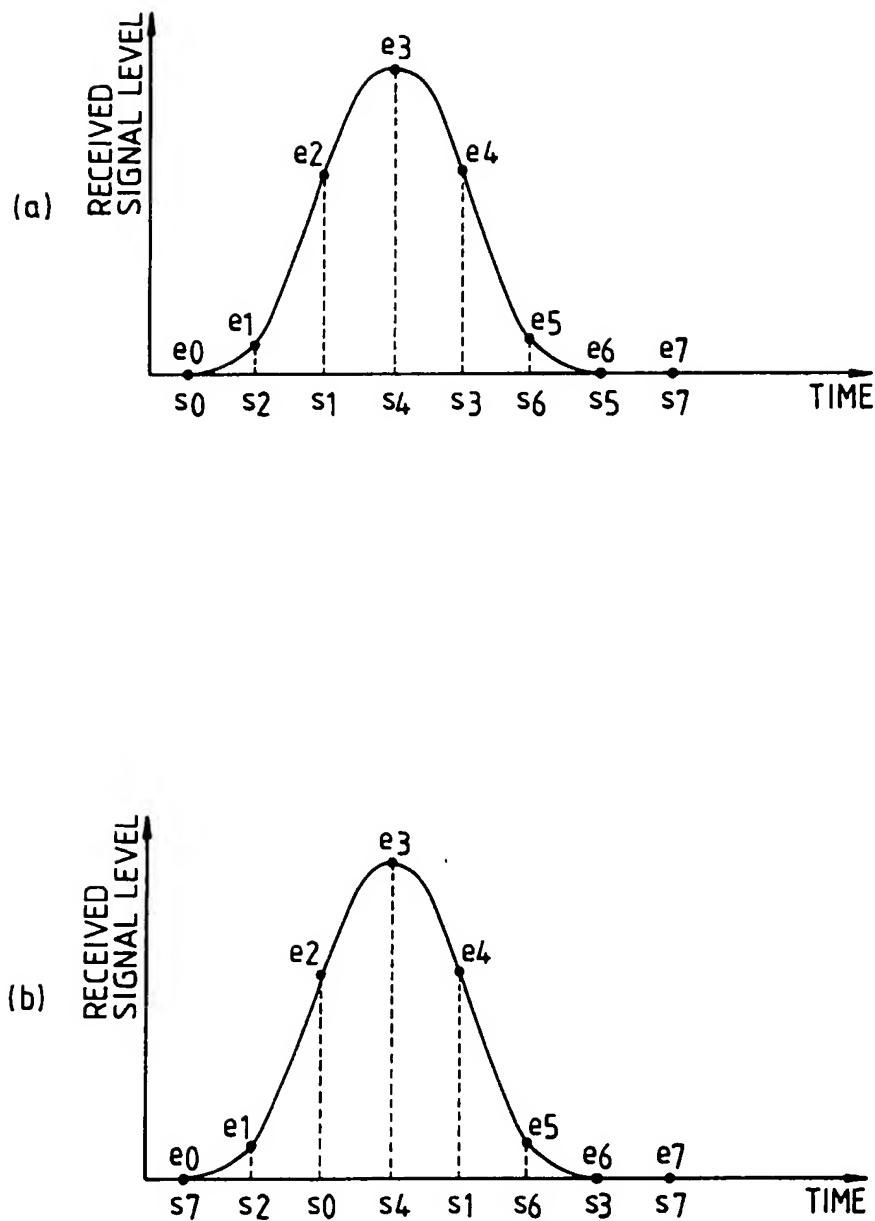


Fig.11



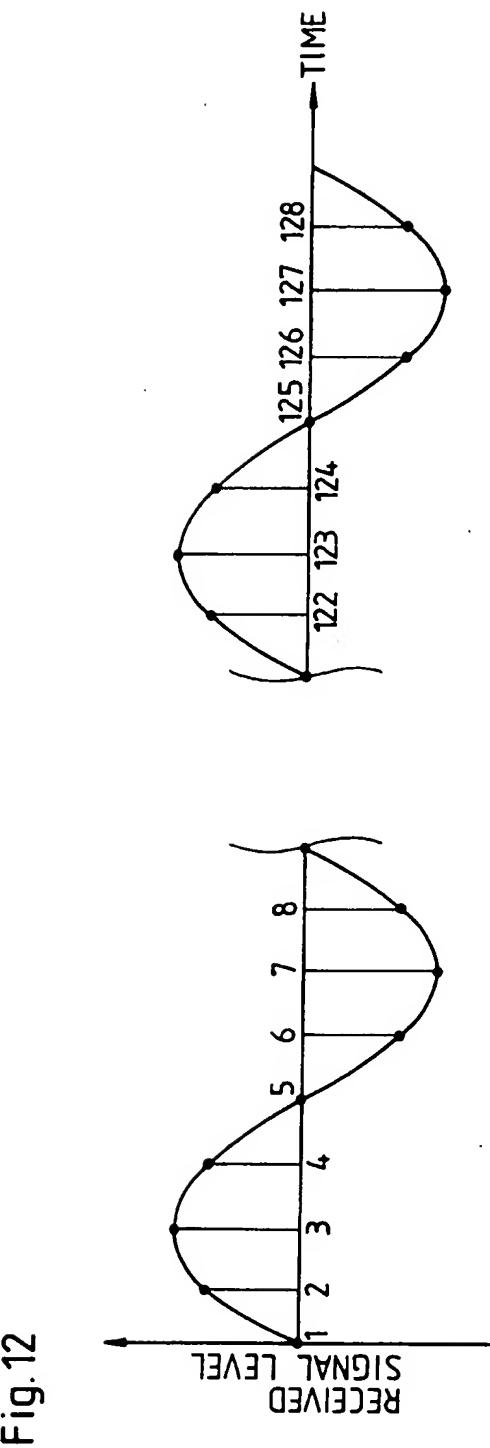


Fig. 13

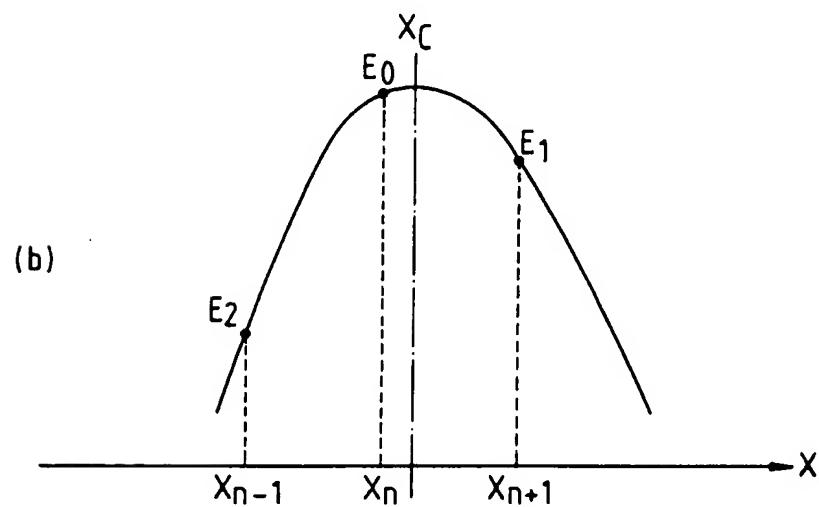
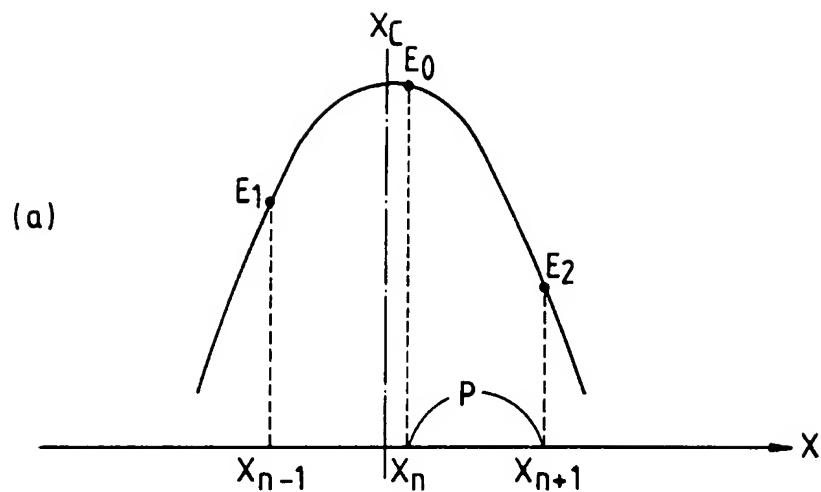


Fig.14

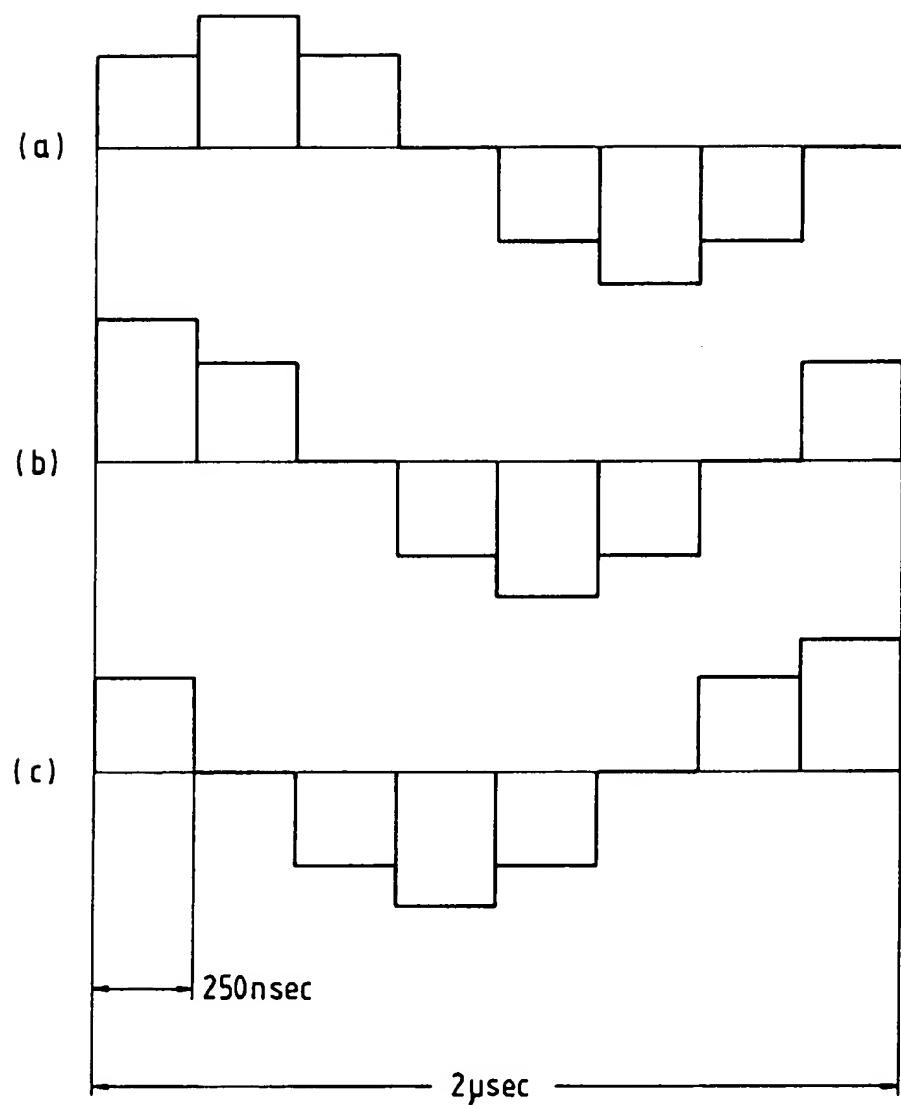


Fig. 15

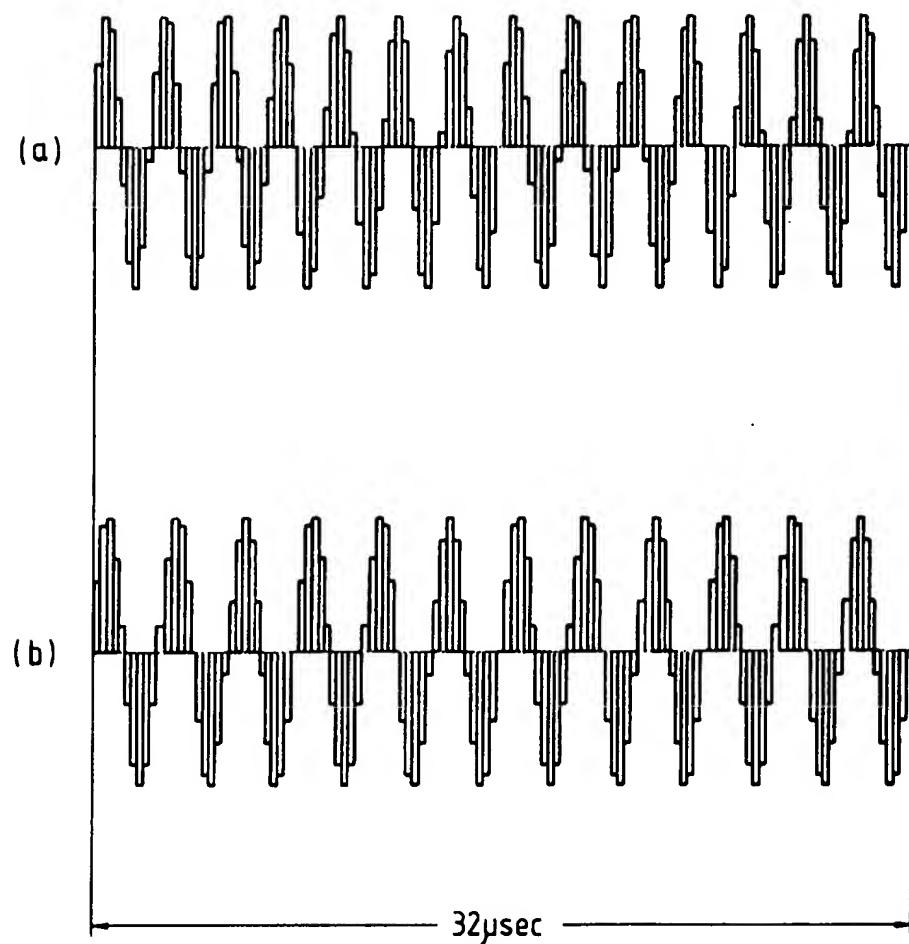
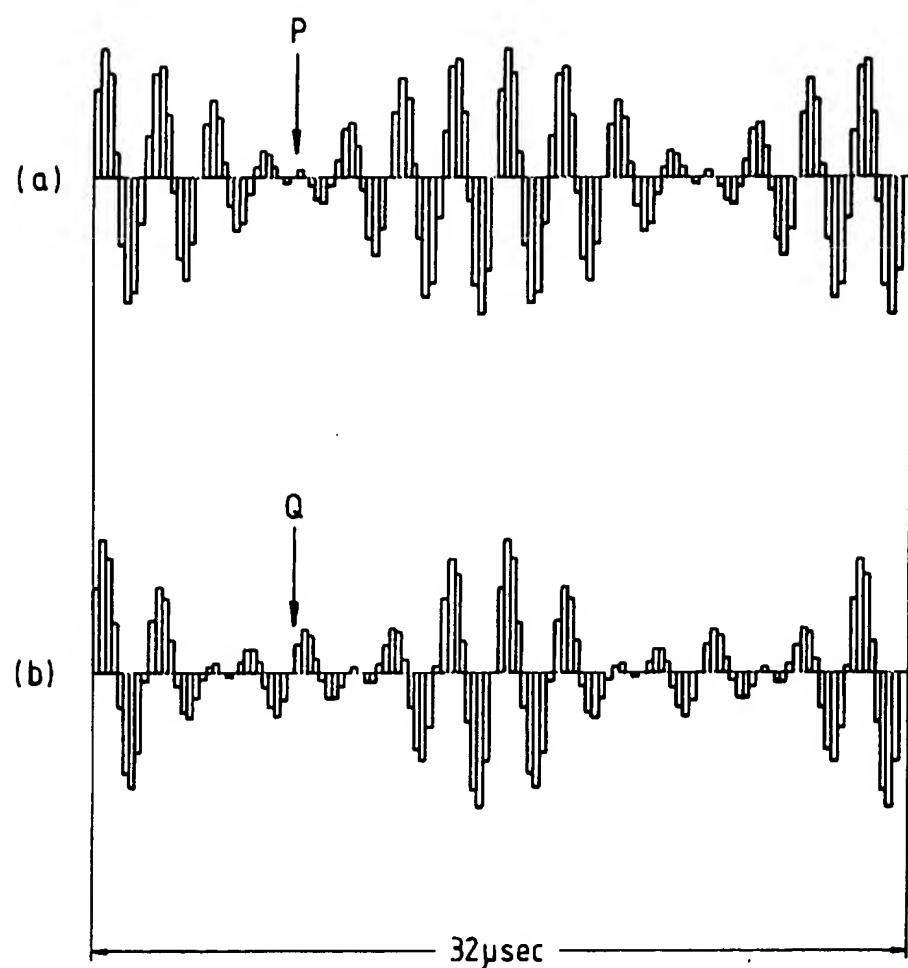


Fig.16



INTERNATIONAL SEARCH REPORT

International Application No. PCT/JP90/01397

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁴

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl⁵ G06F3/03, G06K11/16

II. FIELDS SEARCHED

Minimum Documentation Searched ⁶

Classification System	Classification Symbols
IPC	G06F3/03, G06K11/06-11/16
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁶	
Jitsuyo Shinan Koho	1970 - 1990
Kokai Jitsuyo Shinan Koho	1971 - 1990

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁷

Category ⁸	Citation of Document, ¹⁰ with indication, where appropriate, of the relevant passages ¹¹	Relevant to Claim No. ¹²
A	JP, A, 53-2045 (Seiko Instruments Inc.), January 10, 1978 (10. 01. 78), (Family: none)	1, 3-6
A	JP, A, 1-134618 (Wacom K.K.), May 26, 1989 (26. 05. 89), (Family: none)	2, 4-6
A	JP, A, 61-80327 (PFU K.K.), April 23, 1986 (23. 04. 86), (Family: none)	2, 4-6
...

* Special categories of cited documents: ¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
December 5, 1990 (05. 12. 90)	December 25, 1990 (25. 12. 90)
International Searching Authority Japanese Patent Office	Signature of Authorized Officer